

World Sailing In-Build Validation (WS IBV)**Keel¹ structural integrity: Offshore monohulls in Categories 0, 1 & 2****Report—08 September 2017**

Stage 1 of the proposed WS IBV scheme is detailed below. This will form the basis of a WS Submission in November 2017 and subsequent changes to:

- *the Offshore Special Regulations (OSR) and;*
- *the text of the Structural Plan Review (SPR) on the WS website.*

Document templates have been prepared and follow the main body of this report in the following order:

- Nomination form: Identification of defined roles
- Guidance note for requirements: Keel structural designer including Appendix D1
- Guidance note for requirements: Keel installation designer
- Guidance note for requirements: Keel manufacturer
- Appendix M1: Photographic record
- Appendix M2: Certificate of keel manufacture
- Guidance note for requirements: Keel installer
- Appendix M3: Certificate of keel installation
- Guidance note for requirements: Keel surveyor
- Appendix M4: Certificate of keel survey

*An informative **presentation with executive summary and IBV process flow chart** follow the document templates.*

The OSR and SPR text re-writes shall be prepared by WS to include:

- New SPR requirements to be flagged in OSR
- Alterations to keel: requirement to re-submit IBV
- Damage and repair
- Periodic survey (recommendation)
- Composite construction-hull structure adjacent to keel attachment
- Fair notice provision-IBV continuing development

¹ **Keel:** yacht's primary ballast keel, fixed, lifting or canting, that provides majority of righting moment.

The WS IBV will:

1. Form part of the requirements within the WS Offshore Special Regulations (OSR) 3.03.
2. Be implemented for newly-constructed yachts from Age Date 01/20 (tbc).
3. Apply to Mo0,1,2.
4. Also be suitable for use in the event of newly-constructed keels fitted to existing yachts.
5. Not be implemented on existing keels, although regular inspection and survey of existing yachts and their keels, particularly after grounding, is strongly encouraged and should be a recommendation in the OSR.
6. Be integrated into the existing WS OSR Structural Plan Review (SPR). (Existing version at http://www.sailing.org/classesandequipment/offshore/plan_review.php). The SPR will be conducted in two stages: *Interim* and *Final*.
7. Initially be launched as *Stage 1*, with application to:
 - 7.1 Metal keels (fixed, lifting and canting) that rely primarily on the reliability of welds and/or cast or forged or machined metal connections that are critical for **structural integrity**².
 - 7.2 The target budget cost for the added structural plan review and survey requirements of Stage 1 is €5K. DNVGL has been asked to provide further support for the feasibility of this budget.
8. Be expandable to include:
 - 8.1 Composite keels (*Stage 2*).
 - 8.2 Further consideration of hull structure adjacent to the keel attachment (*Stage 3*). While technically possible, this has been excluded on cost grounds at this stage³, mainly related to the need for multiple surveys at more than one location and involving different survey skill sets.
9. Address four key aspects that are currently not included in the SPR:
 - 9.1 Firstly, keel structural design—details: requirements for all castings, forgings, machining, welds, welding standards, visual inspection during manufacture, liquid penetrant testing, hold-points for NDT, tolerances and materials⁴.

² **Structural integrity:** In this context, welds and other design details that must not fail, in order to prevent catastrophic loss of the keel, leading to capsize and/or sinking.

³ Budget cost for increased scope of Structural Plan Review (SPR) and Certificate of keel survey = max.€5K.

⁴ See Appendix D-1 for sample indicative design notes (guidance only).

9.2 Secondly, manufacture of the keel—an inspection and test plan during manufacture (**ITP-M**) of the keel and part of the SPR submission, that includes:

- 9.2.1 Welding, casting, forging and machining to recognized national or international standards: check of compliance of preparation and condition of completed welds, grain flow in cast connections etc.
- 9.2.2 Written welding plan.
- 9.2.3 Any welding procedures that deviate from the recognized standard.
- 9.2.4 Non-destructive testing (NDT) of welds and/or castings/forgings by a qualified organization/agency detailing test methods and results obtained.
- 9.2.5 Compulsory *hold-points* during keel manufacture to facilitate NDT, inspection and photographic record (see 9.2.6 and 10.5.2.4).
- 9.2.6 Welding by qualified welding personnel.
- 9.2.7 A formal, annotated photographic record, compiled by the keel manufacturer throughout the manufacture of the keel, showing key internal and external welds, castings, forged and/or machined parts and their design details and structural features as-constructed, before they become hidden from view.
- 9.2.8 Provision of mechanical property data sheets for the materials used to manufacture the subject keel.

9.3 Thirdly, keel installation design to the yacht's hull: Written procedure to be included in the SPR keel structural design documentation and cross-referenced in the yacht's SPR hull structure design documentation, including:

- 9.3.1 Installation principle: flush-mounted; non-flush-mounted: "male" keel wedge into a "female" girder; T-flange; lifting keel; canting keel etc. See ISO12215-9 Annex 3.
- 9.3.2 Assembly tolerances.
- 9.3.3 Dry-fit trial installation procedure.
- 9.3.4 Permitted corrective actions, re-work actions, disqualifying actions.
- 9.3.5 Rigid bedding compound mechanical properties, particularly cured compressive strength, minimum and maximum permitted thickness, provisions to exclude entrapped air and maintain keel fastener pre-load.

- 9.3.6 Fastener pre-load and tightening torque. Fastener materials. Thread forms. Greased or ungreased threads. Dimensions, materials and fit of washer plates and bedding compounds.
- 9.3.7 Safety securing measures.
- 9.3.8 Corrosion prevention.
- 9.4 Fourthly, survey of SPR design documentation for keel structural design and keel installation design and physical survey of the keel installation.
10. Nominate the following **defined roles**:
- 10.1 The **structural designer**⁵ of the **keel structural design**⁶ responsible for the SPR submission and **structural integrity** of the **keel structural design**.
- 10.2 The **structural designer** of the **keel installation design**⁷ responsible for the SPR submission and **structural integrity** of the attachment of the keel to the yacht's hull.
- 10.3 The **keel manufacturer**⁸, noting if the **keel manufacturer** also assumes the role of **structural designer** of the **keel structural design** and/or **keel installation design**. The **keel manufacturer** is responsible for designing and undertaking the **inspection and test plan during manufacture (ITP-M)** which is to be included in the submission for interim and final OSR Structural Plan Review, confirming:
- 10.3.1 That the interim SPR-reviewed **keel structural design** and (as needed) **keel installation design** documentation have been used to manufacture the keel.
- 10.3.2 That welding, casting, forging and machining have been performed to a recognized national or international standard⁹.
- 10.3.3 That satisfactory NDT test reports for the welds, castings, forgings and machining have been completed.

⁵ **Structural designer**: the design authority, corporate or individual, assuming responsibility for the engineering design of the **keel structural design** and/or **keel installation design**.

⁶ **Keel structural design**: those aspects of the design and documentation of the keel concerned with its structural adequacy.

⁷ **Keel installation design**: those aspects of the design and documentation of the attachment of the keel to the yacht's hull.

⁸ **Keel manufacturer**: the manufacturer, corporate or individual, assuming responsibility for the fabrication of the **keel structural design**.

⁹ AWS D1.1 *Structural Welding Code-Steel*; or BS-EN-ISO 15614 *Specification and qualification of welding procedures for metallic materials*; or AS/NZS 1554 *Structural steel welding*; or Other: to be nominated for consideration by the Notified Body conducting the Structural Plan Approval. Casting, forging and machining standards to be nominated.

10.3.4 That a written welding plan has been followed, including:

- Details of weld categories used.
- Details of surface finishes.
- Schedule of welding materials.
- Explanatory notes on welding procedures where these differ from the nominated standard.
- Qualification requirements for welders.
- List of quality assurance documents: Production records; NDT-plan.
- Explanatory notes on visual inspection of welds, liquid penetrant tests to external and internal welds, permitted tolerances, hold points for NDT.

10.3.5 That a formal, annotated photographic record has been compiled by the **keel manufacturer** and appended to the **ITP-M**. The photographic record shall include:

- Sufficient resolution and quality.
- Weld preparation areas.
- Weld types. Castings. Forgings. Machined elements and faces.
- The geometry and assembly sequence specified in the **keel structural design**.
- Weld locations, cross-referenced to the **keel structural design**.
- Post-weld fabrication, before and after any finish grinding.
- Evidence of visual inspection and NDT procedures undertaken.
- The finished keel, before and after the application of protective coatings.

10.3.6 Only qualified welding personnel have been employed to manufacture the keel.

10.3.7 Mechanical property data sheets for the materials used to manufacture the keel have been provided.

10.3.8 The **keel manufacturer** shall issue a signed *Certificate of keel manufacture* upon completion of manufacture.

- 10.4 The **keel installer**¹⁰ that undertakes the physical keel installation and issues a signed *Certificate of keel installation* upon completion of the keel installation.
- 10.5 The **keel surveyor**¹¹ responsible for undertaking an **inspection and test plan during survey (ITP-S)** which ensures:
- 10.5.1 That the **keel manufacturer** has issued a signed *Certificate of keel manufacture* confirming that the **ITP-M** is attached and has been reviewed by the NB during the interim SPR process and used by the manufacturer to fabricate the keel.
- 10.5.2 That the keel has been installed on the yacht's hull in accordance with **the keel installation design** by the **keel installer** and that the **keel installer** has issued a signed *Certificate of keel installation* indicating that the **keel installation design and ITP-S** have been adhered to.
- 10.5.3 That the **keel surveyor** has attended and witnessed the installation of the keel to the yacht's hull, using best professional practice to ensure that the **keel installer** has installed the keel in accordance with the **keel installation design**.
- 10.5.4 The **keel surveyor** shall retain copies of the *Certificate of keel manufacture* and *Certificate of keel installation* and when satisfied that steps 10.5.1, 10.5.2 and 10.5.3 have been satisfactorily completed, shall issue to WS, a *Certificate of keel survey* attaching the *Certificate of keel manufacture* and *Certificate of keel installation*. This will allow the issue by World Sailing of the Final OSR Plan Review Certificate.

¹⁰ **Keel installer:** the entity, corporate or individual, assuming responsibility for the attachment of the keel to the yacht's hull:



¹¹ **Keel surveyor:** Must have recognized and current qualifications in yacht surveying, such as an accredited service supplier recognized by WS-recognized Notified Body or holder of a Lloyd's Maritime Academy Diploma in Marine Surveying or a SAMS-Accredited Marine Surveyor or other recognized equivalent (varies by country). Must have a demonstrated track record of experience in surveying performance yacht structures and capable of issuing a *Certificate of keel survey*.

- 11 Include additional content (remarks in the SPR text, flagged in the OSR) that address:
- 11.1 Damage and repair. A requirement that “In the event of substantial damage and repair to a **keel** reviewed under the scheme, the repair of the **keel** and its installation shall be subject to re-survey”.
 - 11.2 Periodic survey-recommendation. “Periodic survey of a **keel** reviewed under the scheme shall be undertaken every three years or after any significant grounding or collision”.
 - 11.3 Alterations. “In the event of alterations to a previously approved **keel structural design** and **keel installation design**, re-survey is required”.
 - 11.4 Hull structure adjacent to the keel attachment. If of composite construction, the SPR text shall include:
 - 11.4.1 “Keel bolt washer plate dimensions and fit: Attention is drawn to ISO12215-9, particularly Annex D”.
 - 11.4.2 “Composite laminate through-thickness behaviour is resin matrix dominant: Through-thickness loading in way of the keel attachment cannot be avoided and steps must be taken so that composite elements ensure a fibre-dominant or at least, structurally compensated, load transfer. Overloading, loose keel fastenings and grounding have been found to result in fatigue and catastrophic failure. Attention is drawn to DNVGL, *Rules for Classification and Construction*, Part I Ship Technology, Section 3 Special Craft, Part 8 – Structural Design of TP52 Racing Yachts Version 2015-05-27, sections 3.4, 3.8 & 3.10”.
 - 11.4.3 Fair notice. The OSR and SPR texts will state that the scheme is under continuing development, in terms of design, manufacturing and survey requirements. Further treatment of the following is anticipated:
 - Composite keels;
 - Hull structure adjacent to the keel attachment;
 - Keels of novel design and construction presented for SPR.
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Nomination Form—Defined roles. Completed record to be on file at World Sailing prior to issue of final SPR.

<i>In relation to</i>	
WS Certificate Identification Number:	
Date of Certification:	
<u>YACHT DETAILS</u>	
Name of Yacht Design	
Yacht Name (if known)	
Design Series Number (if applicable)	
Designer	
Builder/Manufacturer	
Mass of displacement – mLDC (kg)	
Major construction material	
Other notes (e.g. modifications to standard specification)	
<u>NOTIFIED BODY DETAILS</u>	
Name of Notified Body	

DEFINED ROLES	
The structural designer ^[1] of the keel ^[2] structural design ^[3] responsible for the keel SPR submission and structural integrity ^[4] of the keel structural design :	
The structural designer of the keel installation design ^[5] responsible for the keel installation SPR submission and structural integrity of the attachment of the keel to the yacht's hull:	
The keel manufacturer ^[6] responsible for designing and undertaking the inspection and test plan during manufacture (ITP-M) and issuing a signed <i>Certificate of keel manufacture</i> :	
The keel installer ^[7] responsible for the keel installation and issuing a signed <i>Certificate of keel installation</i> :	
The keel surveyor ^[8] responsible for undertaking an inspection and test plan during survey (ITP-S) and issuing a <i>Certificate of keel survey</i> :	

¹ **Structural designer:** the design authority, corporate or individual, assuming responsibility for the engineering design of the **keel structural design** and/or **keel installation design**.

² **Keel:** yacht's primary ballast keel, fixed, lifting or canting, that provides majority of righting moment.

³ **Keel structural design:** those aspects of the design and documentation of the keel concerned with its structural adequacy.

⁴ **Structural integrity:** in this context, welds and other design details that must not fail, in order to prevent catastrophic loss of the keel, leading to capsize and/or sinking.

⁵ **Keel installation design:** those aspects of the design and documentation of the attachment of the keel to the yacht's hull.

⁶ **Keel manufacturer:** the manufacturer, corporate or individual, assuming responsibility for the fabrication of the **keel structural design**. To note if the **keel manufacturer** also assumes the role of **structural designer** of the **keel structural design** and/or **keel installation design**

⁷ **Keel installer:** the entity, corporate or individual, assuming responsibility for the attachment of the keel to the yacht's hull

⁸ **Keel surveyor:** must have recognized and current qualifications in yacht surveying, such as an accredited service supplier recognized by WS-recognized Notified Body or holder of a Lloyd's Maritime Academy Diploma in Marine Surveying or a SAMS-Accredited Marine Surveyor or other recognized equivalent (varies by country). Must have a demonstrated track record of experience in surveying performance yacht structures.

Guidance note¹: Requirements—Structural designer of the keel structural design²*Keel structural design—details*

In order to meet the design allowables used in design calculations, the specifications and drawings forming the SPR submission for the keel structural design shall include³, as applicable:

- Requirements for all welds
 - Welding standards
 - AWS D1.1 *Structural Welding Code-Steel*; or BS-EN-ISO 15614 *Specification and qualification of welding procedures for metallic materials*; or AS/NZS 1554 *Structural steel welding*; or Other: to be nominated for consideration by the Notified Body conducting the Structural Plan Approval. Casting, forging and machining standards to be nominated by **structural designer of the keel structural design**.
 - Visual inspection during manufacture.
 - Liquid penetrant testing.
- Hold-points for NDT.
- Instructions for dimensional tolerances.
- Instructions for heat treatment.
- Notes for corrosion prevention.
- Notes on material compatibility and avoidance of contact between dissimilar metals.
- Notes on avoiding fatigue.
- Material specifications and mechanical property data sheets.
- Requirements for all castings.
- Requirements for all forgings.
- Requirements for all machining.
- The geometry and assembly sequence.
- Material mechanical properties and supporting data sheets.

¹ Guidance note to assist the **structural designer** of the **keel structural design**. Detail requirements remain the professional responsibility of the designer and must satisfy the WS-recognized Notified Body conducting the SPR.

DEFINED ROLES The structural designer ^[1] of the keel ^[2] structural design ^[3] responsible for the keel SPR submission and structural integrity ^[4] of the keel structural design :	
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¹ **Structural designer**: the design authority, corporate or individual, assuming responsibility for the engineering design of the **keel structural design** and/or **keel installation design**.

² **Keel**: yacht's primary ballast keel, fixed, lifting or canting, that provides majority of righting moment.

³ **Keel structural design**: those aspects of the design and documentation of the keel concerned with its structural adequacy.

⁴ **Structural integrity**: in this context, welds and other design details that must not fail, in order to prevent catastrophic loss of the keel, leading to capsize and/or sinking.

³ Refer to Appendix D1 for a typical example (guidance only).

Appendix D1 (guidance only)

WELD CATEGORY & SURFACE FINISH: 1B II (a)

MATERIALS: UNS S31803 - SAF 2205 duplex stainless steel and matching pre-qualified welding consumables.

All consumables to be designated low hydrogen.

WELDING PROCEDURE NOTES:

- All external welds to be continuous - fabrication must be waterproof in finished state.
- Welds not to terminate in corners.
- Full strength butt welds (full penetration) to use matching strength consumables.
- All welds to be stringer bead welds.
- Welding personnel: All operators to be minimum AS1554 qualified in the appropriate low hydrogen process.
- All welds above 6mm to be multi-pass.
- All weld procedures to be pre-qualified & fully documented.

INSPECTION:

- 100% visual scanning all welds.
- 100% liquid penetrant (LP) on all external welds.
- 25% LP of internal welds, including specific areas called up on this drawing.
- Post weld inspection to be carried out a minimum of 24 hours after all welding has stopped.

TOLERANCES:

- O/A tolerance is +/- 2.5mm on straightness, twist and position as measured from a flat plane or table.
- Outer skin is theoretically 1mm below finished profile to allow for filling and paint.
- Dimensional tolerance on outer skin is -0.5mm/-3.5mm from theoretical profile. This allows for filling, fairing and final painting system to achieve desired profile. Fabricator must manufacture and use profile templates as per detail on Drawing xxx00y sheet N to determine conformity.

HOLD POINTS:

(Photographic record at least all stages marked *)

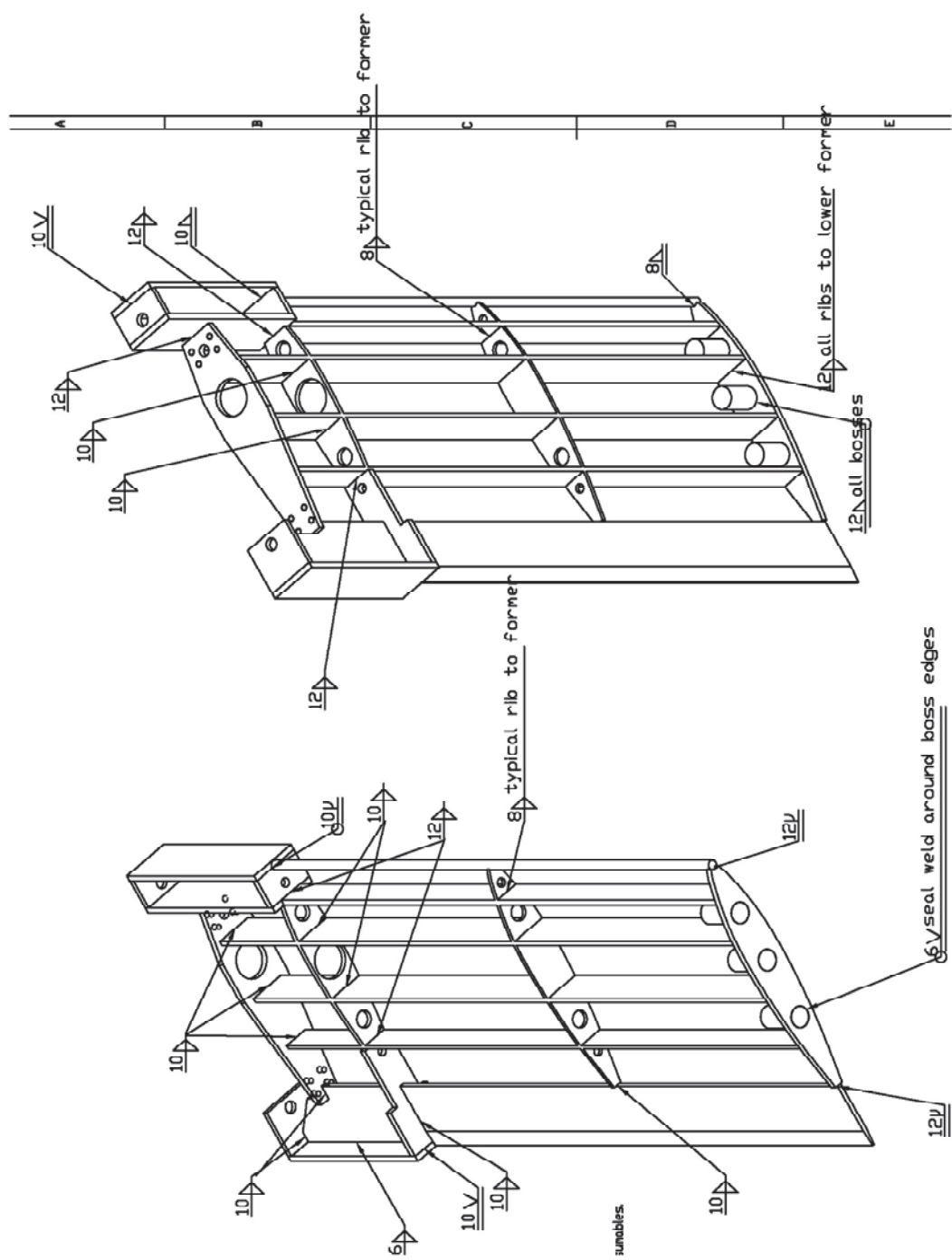
A inspection and test plan (ITP-M) is to be prepared by the manufacturer and sighted by the surveyor, stating

hold points for inspection, these to include:

1. * Lower bolt bosses welded to lower former. Visual 100% LP. Perform NDT.
2. Longitudinals, leading edge bar and trailing edge plate tacked to formers. Dimensional check for symmetry, position and overall trueness. Record dimensions.
3. * Internal frame welded. LP & dimensional check. Check completeness and distortion. Perform NDT.
4. Skins tacked. Dimensional check of slot weld positioning, overall size, thickness, taper and flatness.

Check foil form at four sections before welding.

5. * Skins welded. Dimensional check, LP and visual check of all slot welds. Weld completeness, distortion, overall size, thickness, taper and flatness. Perform NDT. Record dimensions.
6. Guide plates tacked in position. Dimensional check of position, parallel and taper.
7. Welding of all guide plates, webs and closing plates complete. LP remaining external welds and check overall dimensions.
- 8.* Machining complete. Check overall dimensions and integrity of any welds (LP) in machined areas. Perform NDT.



Guidance note¹: Requirements—Structural designer of the keel installation design²*Keel installation design—details*

In order to meet the design allowables used in design calculations, the specifications and drawings forming the SPR submission for the **keel structural design** shall include, as applicable:

- Written procedure for the installation of the keel to be included in the SPR keel structural design documentation and cross-referenced in the yacht's SPR hull structure design documentation
 - Installation principle: flush-mounted; non-flush-mounted: "male" keel wedge into a "female" girder; T-flange; lifting keel; canting keel etc. See ISO12215-9 Annex 3.
 - Assembly tolerances.
 - Dry-fit trial installation procedure.
 - Permitted corrective actions, re-work actions, disqualifying actions.
 - Rigid bedding compound mechanical properties, particularly cured compressive strength, minimum and maximum permitted thickness, provisions to exclude entrapped air and maintain keel fastener pre-load.
 - Fastener pre-load and tightening torque. Fastener materials. Thread forms. Greased or ungreased threads.
 - Dimensions, materials and fit of washer plates and bedding compounds.
 - Safety securing measures.
 - Corrosion prevention.
 - Notes on material compatibility and avoidance of contact between dissimilar metals.
 - Notes on avoiding fatigue.
 - Material mechanical properties and supporting data sheets.

¹ Guidance note to assist the **structural designer** of the **keel installation design**. Detail requirements remain the professional responsibility of the designer and must satisfy the WS-recognized Notified Body conducting the SPR.

DEFINED ROLES	
² The structural designer of the keel installation design ^[5] responsible for the keel installation SPR submission and structural integrity of the attachment of the keel to the yacht's hull:	

Structural designer: the design authority, corporate or individual, assuming responsibility for the engineering design of the **keel structural design** and/or keel installation design.

Keel: yacht's primary ballast keel, fixed, lifting or canting, that provides majority of righting moment.

Structural integrity: in this context, welds and other design details that must not fail, in order to prevent catastrophic loss of the keel, leading to capsize and/or sinking.

⁵ **Keel installation design:** those aspects of the design and documentation of the attachment of the keel to the yacht's hull.

Guidance note¹: Requirements—Keel manufacturer²*Manufacture of keel: Quality—details*

The keel manufacturer shall design and adhere to an **inspection and test plan during manufacture (ITP-M)** forming part of the SPR submission which shall include, as applicable:

1. Written specification and plan for each of the following manufacturing methods, as used for the keel
 - Welding
 - Nomination of recognized national and/or international standards employed.
 - Written welding plan
 - Details of weld categories used.
 - Details of surface finishes.
 - Schedule of welding materials.
 - Explanatory notes on welding procedures where these differ from the nominated standard.
 - Qualification requirements for welders.
 - List of quality assurance documents: Production records; NDT-plan.
 - Any welding procedures that deviate from the recognized standard.
 - Non-destructive testing (NDT) of welds by a qualified organization/agency detailing test methods and results obtained.
 - Compulsory *hold-points* during keel manufacture to facilitate NDT and inspection³.
 - Explanatory notes on visual inspection of welds, liquid penetrant tests to external and internal welds, permitted tolerances, hold points for NDT.
 - Check of compliance of preparation and condition of completed welds.
 - Casting
 - Nomination of recognized national and/or international standards employed.
 - Written casting plan with emphasis on grain flow in cast load-bearing connections.
 - Casting by qualified personnel.
 - Any casting procedures that deviate from the recognized standard.

¹ Guidance note to assist the keel manufacturer. Detail requirements remain the professional responsibility of the keel manufacturer and must satisfy the WS-recognized Notified Body conducting the SPR.

DEFINED ROLES	
The keel manufacturer ^[6] responsible for designing and undertaking the inspection and test plan during manufacture (ITP-M) and issuing a signed <i>Certificate of keel manufacture</i> : ²	

⁶ **Keel manufacturer:** the manufacturer, corporate or individual, assuming responsibility for the fabrication of the **keel structural design**. To note if the **keel manufacturer** also assumes the role of **structural designer** of the **keel structural design** and/or **keel installation design**

Keel: yacht's primary ballast keel, fixed, lifting or canting, that provides majority of righting moment.

Structural designer: the design authority, corporate or individual, assuming responsibility for the engineering design of the **keel structural design** and/or **keel installation design**.

Keel structural design: those aspects of the design and documentation of the keel concerned with its structural adequacy.

Keel installation design: those aspects of the design and documentation of the attachment of the keel to the yacht's hull.

³ Refer Appendix M1 (for guidance only).

- Non-destructive testing (NDT) of castings by a qualified organization/agency detailing test methods and results obtained.
 - Compulsory *hold-points* during keel manufacture to facilitate NDT and inspection.
 - Forging.
 - Nomination of recognized national and/or international standards employed.
 - Written forging plan with emphasis on grain flow in forged load-bearing connections.
 - Forging by qualified personnel.
 - Any forging procedures that deviate from the recognized standard.
 - Non-destructive testing (NDT) of forgings by a qualified organization/agency detailing test methods and results obtained.
 - Compulsory *hold-points* during keel manufacture to facilitate NDT and inspection.
 - Machining.
 - Nomination of recognized national and/or international standards employed.
 - Written machining plan.
 - Machining by qualified personnel.
 - Any machining procedures that deviate from the recognized standard.
 - Non-destructive testing (NDT) of machined components by a qualified organization/agency detailing test methods and results obtained.
 - Compulsory *hold-points* during keel manufacture to facilitate NDT and inspection.
2. A formal, annotated photographic record⁴, compiled by the keel manufacturer throughout the manufacture of the keel, showing (as applicable) key internal and external welds, castings, forged and/or machined parts and their design details and structural features as-constructed, **before they become hidden from view**. For instance, the photographic record would show, as applicable
- Sufficient photographic colour, resolution and quality.
 - Weld preparation areas.
 - Weld types.
 - Castings.
 - Forgings.
 - Machined elements and faces.
 - The geometry and assembly sequence specified in the **keel structural design**.
 - Weld locations, cross-referenced to the **keel structural design**.
 - Post-weld fabrication, before and after any finish grinding.
 - Evidence of visual inspection and NDT procedures undertaken.
 - The finished keel, before and after the application of protective coatings.
3. Provision of mechanical property data sheets for the materials used to manufacture the keel.
4. The final step of the **ITP-M** shall be the issue of the *Certificate of keel manufacture*⁵.

⁴ Refer to Appendix M1 (for guidance).

⁵ Refer to Appendix M2.

Appendix M1 (guidance only)

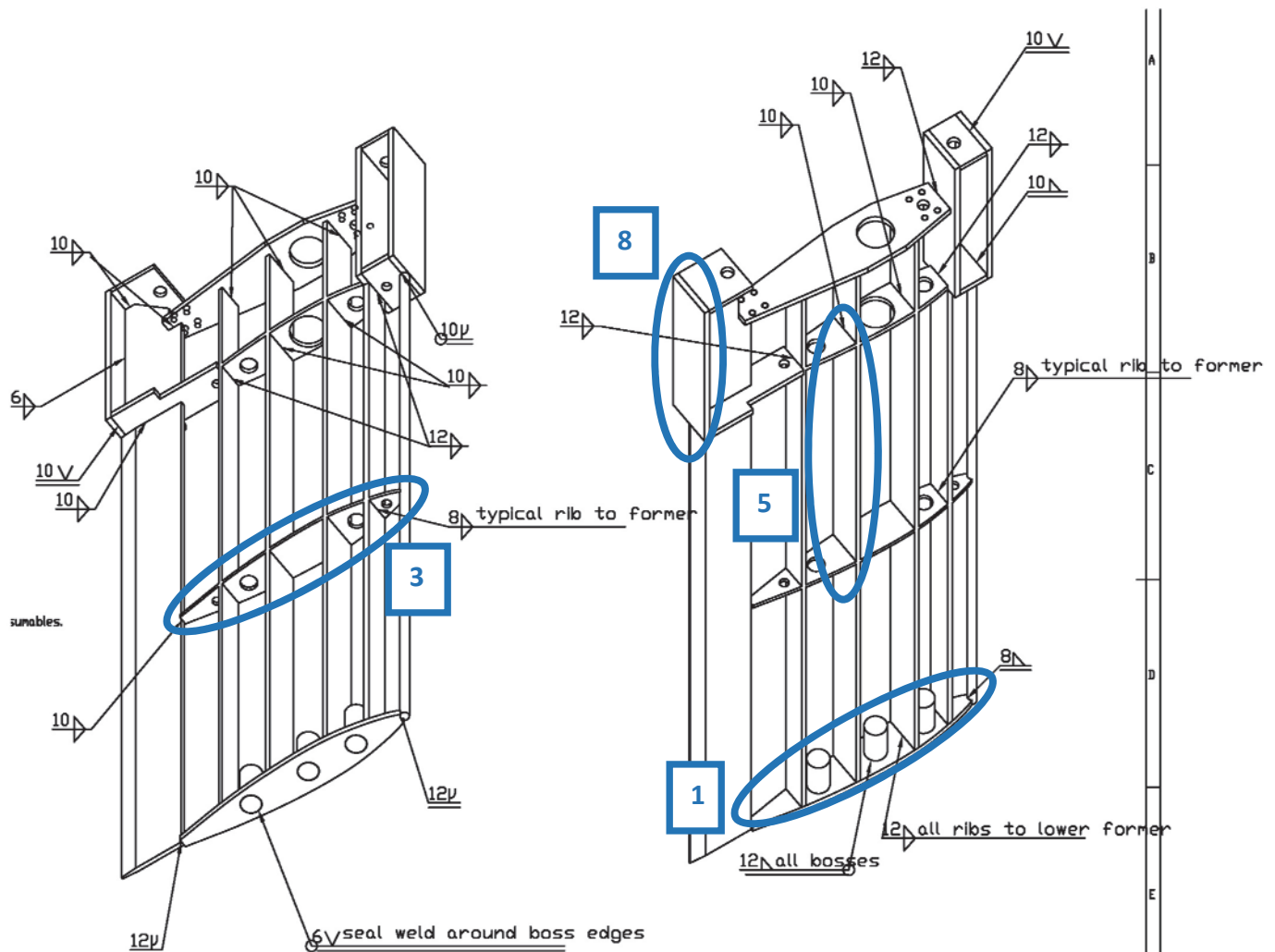
Photographic record at least all stages marked * **NDT** at all stages marked **

Design details and structural features as-constructed, before they become hidden from view

A inspection and test plan (ITP-M) is to be prepared by the manufacturer and sighted by the surveyor, stating

hold points for inspection, these to include:

1. * Lower bolt bosses welded to lower former. Visual 100% LP. **Perform NDT.**
2. Longitudinals, leading edge bar and trailing edge plate tacked to formers. Dimensional check for symmetry, position and overall trueness. Record dimensions.
3. * Internal frame welded-former to rib intersections. LP & dimensional check. Check completeness and distortion. **Perform NDT.**
4. Skins tacked. Dimensional check of slot weld positioning, overall size, thickness, taper and flatness.
Check foil form at four sections before welding.
5. * Skins welded. Dimensional check, LP and visual check of all slot welds. Weld completeness, distortion, overall size, thickness, taper and flatness. **Perform NDT.** Record dimensions.
6. Guide plates tacked in position. Dimensional check of position, parallel and taper.
7. Welding of all guide plates, webs and closing plates complete. LP remaining external welds and check overall dimensions.
- 8.* **Machining complete.** Check overall dimensions and integrity of any welds (LP) in machined areas. **Perform NDT.**



Photographs of feature **1** (bolt bosses-example only)

Min. qty. 3 per feature (three views: side, end and plan)

Min. half A4 page each when printed

10 megapixel min. resolution (Quality of image is important: sharp focus, good lighting, tripod camera mount. Use a proper digital camera, not a smart phone)

Caption all photographs and reference locations to **keel structural design** drawings.

Photographs of feature **3, 5 & 8** (frame, skins, machined welds-examples only)

Min. qty. 3 per feature (i.e three views: side, end and plan)

Min. half A4 page each when printed

10 megapixel min. resolution (Quality of image is important: sharp focus, good lighting, tripod camera mount. Use a proper digital camera, not a smart phone)

Caption all photographs and reference locations to **keel structural design** drawings.

World Sailing

Offshore Special Regulations Structural Plan Review (SPR)

Keel In-Build Validation (IBV)

***Certificate of keel manufacture***

<i>In relation to</i>	
WS Certificate Identification Number:	
Date of Certification:	
<u>YACHT DETAILS</u>	
Name of Yacht Design	
Yacht Name (if known)	
Design Series Number (if applicable)	
Designer	
Builder/Manufacturer	
Mass of displacement – mLDC (kg)	
Major construction material	
Other notes (e.g. modifications to standard specification)	
<u>NOTIFIED BODY DETAILS</u>	
Name of Notified Body	

In accordance with the World Sailing OSR Structural Plan Review In-Build Validation scheme, the keel manufacturer responsible for designing and undertaking the inspection and test plan during manufacture (ITP-M) including NDT, photographic record and issue of this *Certificate of keel manufacture* is detailed below:

Keel manufacturer:	
<i>The undersigned certifies that the keel for the yacht whose details appear above, has been manufactured in accordance with keel structural design drawings:</i>	
Keel structural designer:	
Inspection and test plan during manufacture (ITP-M):	
Signed by duly authorised officer:	
Name (printed):	
Position:	
Date:	

Keel In-Build Validation (IBV)

Guidance note¹: Requirements—Keel installer²*Keel installer—duties and responsibilities*

The **keel installer** shall:

- Follow the **keel installation design**.
- Adhere to an **inspection and test plan during survey (ITP-S)**, provided by the **keel surveyor**. The ITP-S provides independent assurance that the **keel installation design** has been followed by the **keel installer**, so that
 - The installation principle is recognized and understood, as applicable: flush-mounted; non-flush-mounted: “male” keel wedge into a “female” girder; T-flange; lifting keel; canting keel etc. (See ISO12215-9 Annex 3).
 - Assembly tolerances are met.
 - Dry-fit trial installation procedure is undertaken prior to final installation of the keel.
 - Permitted corrective actions, re-work actions, disqualifying actions are understood.
 - Only suitable rigid bedding compounds with sufficient toughness and cured compressive strength are used. Minimum and maximum permissible thickness, provisions to exclude entrapped air and maintain keel fastener pre-load are followed.
 - Fastener pre-load and tightening torque are achieved.
 - Specifications for fastener materials, thread forms, greasing (or not, as specified) of threads are followed.
 - Dimensions, materials and fit of washer plates are followed.
 - Any safety securing measures are followed.
 - Corrosion prevention measures are adhered to.
 - Dissimilar metals are isolated and any corrosion prevention methods are followed.
 - All materials used conform to mechanical property data sheets supplied.
- The **keel installer** shall issue a signed *Certificate of keel installation*³ indicating that the **keel installation design** and ITP-S have been adhered to.

¹ Guidance note to assist the **keel installer**. Detail requirements remain the professional responsibility of the **keel installer** and must satisfy the **keel surveyor** and ITP-S.

DEFINED ROLES	
² The keel installer ^[7] responsible for the keel installation and issuing a signed <i>Certificate of keel installation</i> :	

⁷ **Keel installer**: the entity, corporate or individual, assuming responsibility for the attachment of the keel to the yacht's hull

Keel: yacht's primary ballast keel, fixed, lifting or canting, that provides majority of righting moment.

Keel installation design: those aspects of the design and documentation of the attachment of the keel to the yacht's hull.

Keel surveyor: must have recognized and current qualifications in yacht surveying, such as an accredited service supplier recognized by WS-recognized Notified Body or holder of a Lloyd's Maritime Academy Diploma in Marine Surveying or a SAMS-Accredited Marine Surveyor or other recognized equivalent (varies by country). Must have a demonstrated track record of experience in surveying performance yacht structures.

³ Refer to Appendix M3.

World Sailing

Offshore Special Regulations Structural Plan Review (SPR)

Keel In-Build Validation (IBV)

***Certificate of keel installation***

<i>In relation to</i>	
WS Certificate Identification Number:	
Date of Certification:	
<u>YACHT DETAILS</u>	
Name of Yacht Design	
Yacht Name (if known)	
Design Series Number (if applicable)	
Designer	
Builder/Manufacturer	
Mass of displacement – mLDC (kg)	
Major construction material	
Other notes (e.g. modifications to standard specification)	
<u>NOTIFIED BODY DETAILS</u>	
Name of Notified Body	

In accordance with the World Sailing OSR Structural Plan Review In-Build Validation scheme, the keel installer responsible for installing the keel and issuing this *Certificate of keel installation* is detailed below:

Keel installer:	
<i>The undersigned certifies that the keel for the yacht whose details appear above, has been installed in accordance with keel structural installation drawings and the inspection and test plan during survey (ITP-S):</i>	
Keel installation designer:	
Keel surveyor:	
Inspection and test plan during survey (ITP-S):	
Signed by duly authorised officer:	
Name (printed):	
Position:	
Date:	

Guidance note¹: Requirements—Keel surveyor²*Keel surveyor—duties and responsibilities*

The **keel surveyor** is:

- Responsible for undertaking an **inspection and test plan during survey (ITP-S)** which ensures
 - That the **keel surveyor** has attended and witnessed the installation of the keel to the yacht's hull.
 - That the **keel manufacturer** has issued a signed *Certificate of keel manufacture* confirming that
 - The **inspection and test plan during manufacture (ITP-M)** has been satisfactorily reviewed by the Notified Body during the interim SPR.
 - Used by the **keel manufacturer** to fabricate the keel.
 - The **ITP-M** including photographic record, NDT and material data sheets is attached to the *Certificate of keel manufacture*.
 - That the keel has been installed on the yacht's hull in accordance with **the keel installation design** by the **keel installer** and that the **keel installer** has issued a signed *Certificate of keel installation* indicating that the **keel installation design and ITP-S** have been adhered to.
 - The **keel surveyor** shall retain copies of the *Certificate of keel manufacture* and *Certificate of keel installation* and when satisfied, shall issue a *Certificate of keel survey*³ attaching the *Certificate of keel manufacture* and *Certificate of keel installation*. This will allow the issue by World Sailing of the *Final OSR Plan Review Certificate*.

¹ Guidance note to assist the **keel surveyor**. Detail requirements remain the professional responsibility of the **keel surveyor**.

DEFINED ROLES	
² The keel surveyor ^[8] responsible for undertaking an inspection and test plan during survey (ITP-S) and issuing a <i>Certificate of keel survey</i> :	

⁸ **Keel surveyor**: must have recognized and current qualifications in yacht surveying, such as an accredited service supplier recognized by WS-recognized Notified Body or holder of a Lloyd's Maritime Academy Diploma in Marine Surveying or a SAMS-Accredited Marine Surveyor or other recognized equivalent (varies by country). Must have a demonstrated track record of experience in surveying performance yacht structures. **Keel**: yacht's primary ballast keel, fixed, lifting or canting, that provides majority of righting moment.

Keel installation design: those aspects of the design and documentation of the attachment of the keel to the yacht's hull.

³ Refer to Appendix M4.

World Sailing

Offshore Special Regulations Structural Plan Review (SPR)

Keel In-Build Validation (IBV)

***Certificate of keel survey***

<i>In relation to</i>	
WS Certificate Identification Number:	
Date of Certification:	
<u>YACHT DETAILS</u>	
Name of Yacht Design	
Yacht Name (if known)	
Design Series Number (if applicable)	
Designer	
Builder/Manufacturer	
Mass of displacement – mLDC (kg)	
Major construction material	
Other notes (e.g. modifications to standard specification)	
<u>NOTIFIED BODY DETAILS</u>	
Name of Notified Body	

In accordance with the World Sailing OSR Structural Plan Review In-Build Validation scheme, the keel surveyor responsible for surveying the keel installation and issuing this ***Certificate of keel survey*** is detailed below:

Keel surveyor:	
<i>The undersigned certifies that the keel for the yacht whose details appear above has been installed in accordance with: (i) the NB interim SPR reviewed keel structural installation design and (ii) the inspection and test plan during survey (ITP-S).</i>	<i>The undersigned attended to witness the installation of the keel to the yacht's hull, using best professional practice to ensure that the keel installer has installed the keel in accordance with the keel installation design.</i>
<i>Certificate of keel manufacture attached:</i>	
<i>Certificate of keel installation attached:</i>	
Keel installation designer:	
Keel installer:	
Inspection and test plan during survey (ITP-S) by me:	
Signed by duly authorised officer:	
Name (printed):	
Position:	
Date:	

Keel surveyor: Please Remit

Certificate of keel manufacture***Certificate of keel installation***With this ***Certificate*** to World Sailing

Executive summary

Keel In-Build Validation (IBV): Design, manufacture, testing, quality assurance, survey and certification to ensure that a keel's critical structure is fit-for-purpose.

In the interests of safety of life at sea and good governance, the World Sailing OSR Structural Plan Review (SPR) scheme is to be enhanced by the addition of new mandatory requirements for offshore monohull ballasted yachts in OSR Categories 0, 1 and 2 with effect for Stage 1 of the scheme for yachts with Age Date from 01/20:

- Staged introduction—Stage 1 welded, cast, forged and machined metal keels and their fastenings; Stage 2 composite keels; Stage 3 hull structure adjacent to keel.
- Key roles identified: Structural designer, keel manufacturer, keel installer, keel surveyor, WS-recognized Notified Body.
- Key terms defined: Keel, structural integrity, keel structural design, keel installation design.
- Key processes defined: Inspection and test plan during manufacture (ITP-M), inspection and test plan during survey (ITP-S).
- New certifications: Certificate of keel manufacture, Certificate of keel installation, Certificate of keel survey.
- Structural Plan Review enhancement 1—design detail required for welds and welding practices, casting, forging and machining critical to keel structural integrity.
- Structural Plan Review enhancement 2—minimum acceptable keel manufacturing standard defined by manufacturer in an inspection and test plan, including non-destructive testing conducted by a qualified agency.
- Structural Plan Review enhancement 3—mandatory adherence to a pre-defined keel installation procedure.
- OSR Structural Plan Review to be conducted in two stages: *Interim* and *Final*.
- Survey—Physical inspection by qualified yacht surveyor of (i) Keel installation; (ii) Keel structural design documentation used at installation site; (iii) Certificates of keel manufacture, installation and survey reviewed and submitted by surveyor to World Sailing prior to final OSR Plan Review Certificate issue.
- Target budget cost per boat for additional measures in Stage 1 above and beyond current SPR = €5K (additional plan review + survey). Currently, there is no building inspection or site visits. The current review procedure is plan based only.

World Sailing does not presently require any independent checks that a keel is manufactured or installed as-designed. The IBV scheme is a staged introduction of a plan to address dozens of instances of loss of life at sea in the past two or three decades due to catastrophic loss of keels due to structural failure. Safety, practicality, technology and cost have been considered in the development of the scheme.

- Part of OSR 3.03 *Hull Construction Standards (Scantlings)*
 - *Monohull 0,1,2*
- From Age Date 01/20 (tbc) + new keels on yachts (*Mo0,1,2*)
- Part of OSR *Structural Plan Review (SPR)*, to be conducted in two stages:
 - Interim: pre-installation of keel
 - Final: post-survey of keel

IBV

World Sailing In-Build Validation



Application

Stage 1

Fabricated metal keels with or without cast or forged structural elements, that rely primarily on the reliability of welds that are critical for structural integrity. Cast, forged and machined metal keels. Fixed, lifting and canting.

Stage 2

Composite keels.

Stage 3

Hull structure adjacent to the keel attachment (extra cost).

Defined terms

Keel

A yacht's primary ballast keel, fixed, lifting or canting, that provides the majority of righting moment.

Structural integrity

Welds and other design/fabrication details that must not fail, in order to prevent catastrophic loss of the **keel**, leading to irrecoverable capsized and/or sinking.

Keel structural design

Those aspects of the design and documentation of the **keel** concerned with its **structural integrity**.

Keel installation design

Those aspects of the design and documentation of the attachment of the **keel** to the yacht's hull.

Responsibilities—defined roles (1)

Structural designer—keel structural design

The design authority, corporate or individual, assuming responsibility for the engineering design of the **keel structural design** and submission for interim SPR.

Structural designer—keel installation design

The design authority, corporate or individual, assuming responsibility for the engineering design of the **keel installation design** and submission for interim SPR.

Keel manufacturer

The manufacturer, corporate or individual, assuming responsibility for the fabrication of the **keel structural design**, noting if the **keel manufacturer** also assumes the role of **structural designer—keel structural design** and/or **structural designer—keel installation design**. The **keel manufacturer** is responsible for engaging an NDT agency (as required), designing and undertaking the **inspection and test plan during manufacture (ITP-M)**, to submit it as part of interim SPR and for issuing the signed *Certificate of keel manufacture*.

IBV

World Sailing In-Build Validation



Responsibilities—defined roles (2)

Keel installer

The entity, corporate or individual, assuming responsibility for the installation of the **keel** to the yacht's hull and responsible for issuing the signed *Certificate of keel installation*.

Keel surveyor

Must have a demonstrated track record of experience in surveying performance yacht structures and be responsible for issuing the signed *Certificate of keel survey* and have recognized and current qualifications in yacht surveying*.

* An accredited service supplier recognized by WS-recognized Notified Body or holder of a Lloyd's Maritime Academy Diploma in Marine Surveying or a SAMS-Accredited Marine Surveyor or other recognized equivalent qualification/record of satisfactory experience (varies by country).

Responsibilities—defined roles (3)

Notified Body

As recognized by World Sailing to perform SPR. Applies ISO12215 Parts 5, 8 & 9 and their own rules and analytical methods such as FEA. Scope expanded to review **keel structural design, keel installation design** and **ITP-M** within IBV + remainder of non-keel SPR as currently done. See flowchart on page 13.

World Sailing

Structural Plan Review to be conducted in two stages: *Interim* and *Final*.

Interim: Review of **keel structural design** and **keel installation design** so keel manufacture and installation can proceed.

Final: Receipt of *Certificates of keel manufacture, keel installation* and *keel survey* allows final SPR to be issued.

Keel structural design—details

New mandatory requirements for:

- Welds and welding standards (recognized national or international)*.
- Casting, forging and machining standards **.
- Visual inspection during manufacture.
- Liquid penetrant testing.
- Hold-points for visual inspection and NDT***.
- Tolerances.
- Materials.
- Cross-reference to **keel installation design** documentation.
- Reviewed by Notified Body.

To be included in design submission for interim OSR Structural Plan Review

* AWS D1.1 Structural Welding Code-Steel; or BS-EN-ISO 15614 Specification and qualification of welding procedures for metallic materials; or AS/NZS 1554 Structural steel welding; or Other: to be nominated for consideration by the Notified Body conducting the OSR Structural Plan Approval (SPR).

** Standards to be nominated.

*** NDT program to be nominated by **keel manufacturer**. See **Manufacture** page 10.

Manufacture

Inspection and test plan during manufacture (**ITP-M**) of the **keel**, that includes:

- Welding, casting, forging and machining to a recognized national or international standard: check of compliance of preparation and condition of completed welds.
- Written *welding plan* incl. any welding procedures that deviate from the recognized standard.
- Compulsory *hold-points* during keel manufacture to facilitate NDT, inspection and photographic record.
- Compulsory NDT of welds by a qualified organization (agency) detailing test methods and results obtained.
- Welding by qualified welding personnel, identified in ITP-M.
- A formal, annotated *photographic record*, compiled by the keel manufacturer throughout the manufacture of the keel, showing key internal and external welds, design details and structural features as-constructed, before they become hidden from view.
- Provision of mechanical property data sheets for the materials used to manufacture the keel.
- Manufacture to commence only after satisfactory interim SPR.
- Reviewed by Notified Body.

ITP-M plan is to be included in the submission for interim OSR Structural Plan Review

Completed ITP-M is to be appended to the Certificate of keel manufacture for final OSR Structural Plan Review

Keel installation design to the yacht's hull—details

- Installation principle—description: flush-mounted; non flush-mounted: “male” keel wedge into a “female” girder; T-flange; lifting keel; canting keel etc.
- Assembly tolerances.
- Dry-fit trial installation procedure.
- Permitted corrective actions, re-work actions, disqualifying actions.
- Rigid bedding compound mechanical properties, particularly cured compressive strength, minimum and maximum permitted thickness, provisions to exclude entrapped air and maintain keel fastener pre-load.
- Fastener pre-load and tightening torque.
- Safety securing measures.
- Corrosion prevention.
- Cross-reference to **keel structural design** documentation.
- Reviewed by Notified Body.

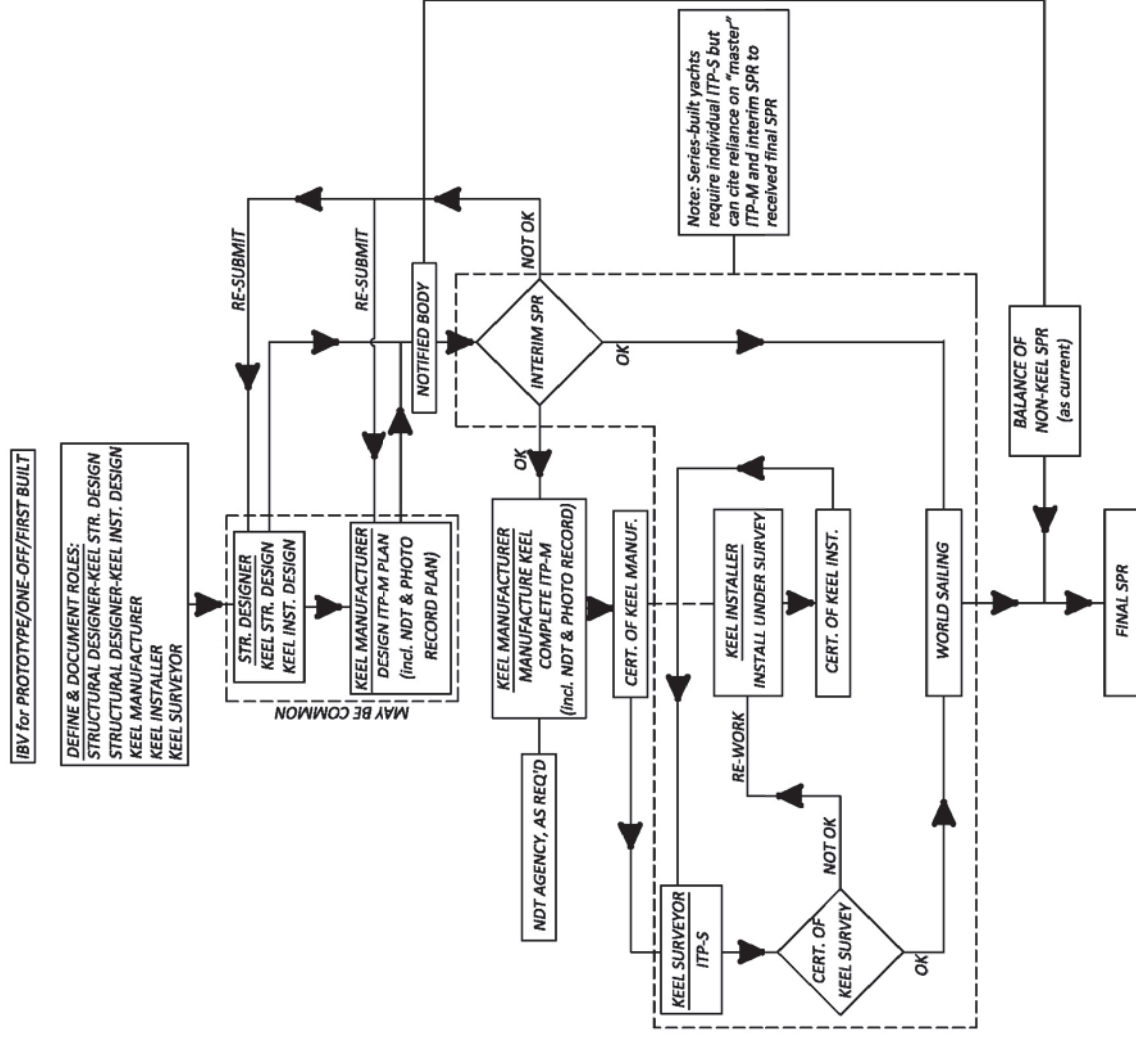
To be included in design submission for interim OSR Structural Plan Review

Inspection and test plan during survey (**ITP-S**) of the keel by the **keel surveyor**, ensuring:

- That the **keel manufacturer** has issued a signed *Certificate of keel manufacture* to confirm that the **ITP-M** has been completed and is appended to the *Certificate*.
- That the **keel installer** has issued a signed *Certificate of keel installation* to confirm that the **keel installation design** has been adhered to.
- That the **keel surveyor** has attended and witnessed the installation of the keel to the yacht's hull, using best professional practice to ensure that the **keel installer** has installed the keel in accordance with the **keel installation design** and when satisfied, issued a *Certificate of keel survey*, attaching the *Certificate of keel manufacture* (with ITP-M appended) and *Certificate of keel installation*.
- *Note: Series-built yachts require individual ITP-S but can cite reliance on "master" ITP-M and interim SPR to received final SPR.*

By **keel surveyor**:

*Certificate of keel manufacture + Certificate of keel installation + Certificate of keel survey → World Sailing
= Final Certificate of Structural Plan Review*



OSR Structural Plan Review—additional requirements (flag in OSR, detail in SPR)

- Add definition *Keel In-Build Validation (IBV): Design, manufacture, testing, quality assurance, survey and certification to ensure that a keel's critical structure is fit-for-purpose.*
- Alterations: “In the event of alterations to a keel the subject of SPR with IBV, re-survey is required”.
- Damage and repair: “In the event of substantial damage and repair to a **keel** reviewed under the scheme, the repair of the **keel** and its installation shall be subject to re-survey”.
- Recommendation—Periodic survey: “Periodic survey of a **keel** reviewed under the scheme shall be undertaken every three years or after any significant grounding or collision”.
- Hull structure adjacent to the keel attachment. If of composite construction, the SPR text shall include:

“Keel bolt washer plate dimensions and fit: Attention is drawn to ISO12215-9, particularly Annex D”.

And;

“Composite laminate through-thickness behaviour is resin matrix dominant: Through-thickness loading in way of the keel attachment cannot be avoided and steps must be taken so that composite elements ensure a fibre-dominant or at least, structurally compensated, load transfer. Overloading, loose keel fastenings and grounding have been found to result in fatigue and catastrophic failure. Attention is drawn to DNVGL, *Rules for Classification and Construction*, Part I Ship Technology, Section 3 Special Craft, Part 8 – Structural Design of TP52 Racing Yachts Version 2015-05-27, sections 3.4, 3.8 & 3.10”.

IBV

World Sailing In-Build Validation



Fair notice

- The OSR and SPR texts will state that the IBV scheme is under continuing development, in terms of design, manufacturing and survey requirements. Further treatment of the following is anticipated:

Composite keels;
Hull structure adjacent to the keel attachment;
Keel of novel design and construction presented for SPR.

TYPICAL SCHEME FLOWCHART_A (08 SEP 2017)



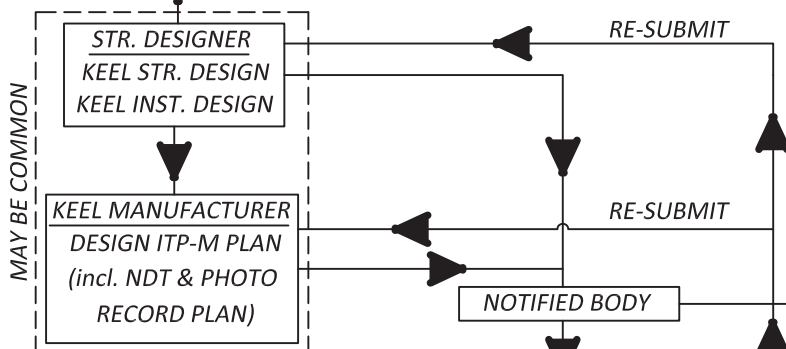
From Age Date 01/20
and new keels on
existing yachts. OSR
Cats Mo0,1,2

Any yacht built under IACS
member (DNVGL, ABS, LR etc.)
classification is considered to
already satisfy these
requirements.

In-Build Validation
of metal keels:
Design/
Manufacture/
Installation.

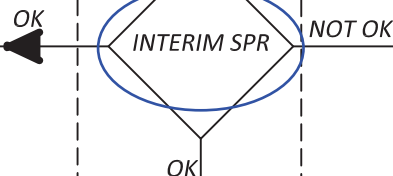
IBV for PROTOTYPE/ONE-OFF/FIRST BUILT

DEFINE & DOCUMENT ROLES:
STRUCTURAL DESIGNER-KEEL STR. DESIGN
STRUCTURAL DESIGNER-KEEL INST. DESIGN
KEEL MANUFACTURER
KEEL INSTALLER
KEEL SURVEYOR



NDT AGENCY, AS REQ'D

KEEL MANUFACTURER
MANUFACTURE KEEL
COMPLETE ITP-M
(incl. NDT & PHOTO RECORD)



CERT. OF KEEL MANUF.

KEEL SURVEYOR
ITP-S

KEEL INSTALLER
INSTALL UNDER SURVEY

CERT. OF KEEL INST.

RE-WORK

NOT OK

OK

WORLD SAILING

BALANCE OF
NON-KEEL SPR
(as current)

FINAL SPR

Note: Series-built yachts
require individual ITP-S but
can cite reliance on "master"
ITP-M and interim SPR to
received final SPR

This means a series-
built yacht only has
individual survey of
the keel installation
to obtain Cert. of
Keel Survey at
reduced cost.

